LDRD Proposal Narrative

Title: Advancing Clean Energy Innovation Decision Science

Motivation: Technological change is driven by such private sector actions as research, development, commercial design, and marketing, in the pressure of economic competition. The rate and direction of technological change that advances public environmental, economic, and security goals, however, is often shaped by public policies and programs, including those that advance the supply of new innovations as well as those that create and shape the markets for new innovations. This LDRD brings empirical data to bear on important theoretical issues in the field of knowledge that concerns the incentives and dynamics by which "clean" energy-related technologies are invented, incorporated into commercial designs, and adopted by consumers and businesses. We coin the phrase "clean energy innovation decision science" (CEIDS) to represent the body of knowledge we hope to advance. This field is a highly fragmented[1] but growing research area that bridges economics, psychology, and sociology.

LDRD Objectives: (1) Develop a world-renowned research center at LBNL that will advance CEIDS by facilitating systematic knowledge creation – based on testable hypotheses and empirical evidence – and enabling modeling improvements. (2) Build a knowledge base for decision-makers. (3) Enhance LBNL's intellectual capabilities and attract new collaborators.

LDRD Research Overview: This LDRD focuses on two main activities, described below. Synergistic tasks involve data advances, technology forecasting, and education and outreach.

Activity 1: Characterizing the Connection between Market Structure and Innovation Processes/Outcomes along Energy-Related Technology Value Chains

Purpose: Discover how market structure relates to innovation processes and outcomes in global energy-related technology/industry value chains.

Significance: Energy-related technology assessments often project costs and performance from current technologies, ignoring how market structure (e.g., industry concentration, extent of product differentiation, entry conditions, vertical integration, etc.) shapes current and future technologies. This omits important information that can add predictive power to assessments. For example, market power, which stems from industry concentration, is one of the major "market failures" that justifies policy intervention to economists and has been the subject of considerable theoretical and empirical research that can inform modeling. Energy-related technologies are well-known to be shaped by market power at the level of transmission and distribution, and may also be shaped by market power at different stages of their global value chains. The extent of market power in energy-related technology value chains is unfortunately not yet a major subject of environmental/energy policy, as it has potentially significant implications including: (1) the potential for artificially constrained prices and/or limitations in goods offered for sale at a given point in a value chain, which can counteract the smooth functioning of other policy instruments (e.g., carbon prices); (2) the theoretical potential to either *positively* or *negatively* affect private sector innovation in a given value chain step;[2] and (3) the implied opportunity to significantly improve forecasting accuracy for a given clean energy value chain step.

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[1] See Kemp, R. and S. Pontoglio (2011). "The innovation effects of environmental policy instruments — A typical case of the blind men and the elephant?" *Ecological Economics* **72**(28): 28-36.

[2] One of the seminal figures in the economics of innovation, Joseph Schumpeter argued for both effects at different times, via his "Mark II" and "Mark I" theories, respectively

Project description: We will systematically characterize the global value chains of several energy supply and demand technologies. For each step in the value chain, we will collect and synthesize secondary and primary data on market structure, innovation processes, and the outcomes of innovation re: technology cost and performance. We are interested in characterizing a distribution of technologies that connect to different schools of economic thought, including industrial organization economics, the economics of innovation, and energy economics (e.g., consumer products, process technologies, distributed vs. centralized energy technologies, etc.). This should allow us to: conduct theoretically-grounded analyses derived from rich empirical data; improve the accuracy of assessments of these technologies; and provide a tool for other researchers to advance this research area through collaboration with LBNL.

Progress to date: We have almost completed a preliminary assessment of market structure and innovation processes/outcomes in the photovoltaics (PV) value chain, as bounded by application (e.g., utility scale solar versus commercial/residential solar). We have also begun considering options for our next technology to assess, including: wind power; combined-cycle natural gas generation; efficient appliances (e.g., refrigerators, clothes washers); or electric vehicles.

Future plans: We will complete our preliminary assessment of PV and at least two other technologies. We will then begin building our prototype information tool and working to automate data collection while we continue conducting preliminary assessments of other technologies. We will submit a paper using the empirical data we are collecting to illustrate our theoretical ideas re: market structure and innovation processes/outcomes in clean energy value chains. We will continue to seek follow-on funding and publicize the results of our efforts.

Activity 2: Resolving the Porter Hypothesis Debate: Empirics on Cost and Quality with Regulatory Compliance

Purpose: Expand knowledge of the likely relationship between a given regulation and how it relates to the quality and cost savings/overruns of a regulated object.

Significance: There is a long-standing debate about whether regulation necessarily hampers innovation[3] or whether it can promote "win-wins" for the environment, firms, and consumers[4]; this latter contention is covered under the term, the "Porter Hypothesis." The unresolved nature of this debate has hindered policy-making at different levels. The proposed project will develop new theory and a related empirical knowledge base that should help resolve this debate.

Project description: The proposed project starts from the premise that both contentions can be correct in different circumstances, and that empirical research and theory development can help estimate the likelihood of each contention holding for a given proposed regulation. This premise is based on two data points: (1) previous work by LBNL authors, including Taylor, which demonstrates through rich empirical evidence that energy efficiency regulations on several domestic appliances often correlate with improved product quality and reduced product costs[5]; and (2) the common experience that a significant redesign of a complex object with interconnected parts (e.g., a kitchen remodel, a rebuilt SF Bay Bridge, etc.) often requires

[3] See Stewart, R.B. (1981). "Regulation, innovation, and administrative law: A conceptual framework." *California Law Review*, 69.

[4] See Porter, M.E. and C. Van der Linde, (1995). "Green and competitive: Ending the stalemate." *Harvard Business Review*, Sept.-Oct. 1995: p. 120.

[5] See Taylor, M.R., C.A. Spurlock, and H.C. Yang (2015). *Confronting Regulatory Cost and Quality Expectations: An Exploration of Technical Change in Minimum Efficiency Performance Standards.* LBNL-1000576.

resolution of a cascading sequence of problems that improves the quality of the object while increasing its cost. In both instances, quality improves with redesign, but in the first scenario costs decline while in the second, costs increase. Our hypothesis is that quality improvements and cost increases occur in both scenarios, but in the appliance scenario they occur in research laboratories and design studios, with relatively small costs that are later counteracted downstream (e.g., through economies of scale in mass production, through larger profits associated with more desirable features incorporated into the newly redesigned products, etc.).

In Activity 2, we will: (1) look for patterns in *ex post* empirical evaluations of regulations which show the quality of the regulated item increasing while the costs either increase or decrease[6]; and (2) develop the economic intuition underlying the observed patterns; and (3) develop one or more empirical cases to test the economic intuition, depending on time and resources.

Progress to date: We have developed our theoretical framework so we now consider four main post-regulation scenarios: (1) improved quality and reduced costs (i.e., the "win-win" Porter Hypothesis scenario); (2) improved quality and increased costs (i.e., the kitchen remodel/Bay Bridge scenario); (3) reduced quality and reduced costs; and (4) reduced quality and increased costs. Armed with this theoretical framework, we have been systematically locating and coding *ex post* evaluations of the hundreds of regulations considered in the 19 Annual Reports to Congress by OIRA on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act (these reports cover regulations issued in 1997-2016).

Future plans: Once we finish systematically compiling examples of the four scenarios (if they exist), we will explore what these examples have in common. We will then work on two follow-on tasks: (1) developing the economic theory that helps explain the observed scenarios and examples; and (2) engaging in qualitative research with subjects who are knowledgeable about the development process underlying examples of the four scenarios. We will begin the latter task by focusing on products that fit with the Porter Hypothesis scenario (probably refrigerators and clothes washers, due to data availability). We will continue to seek follow-on funding and publicize the results of our efforts, including through the submission of journal articles.

Development Opportunities: The proposed projects tackle important CEIDS problems in such a way that they advance the science, raise the visibility of LBNL, and grow internal capabilities (e.g., tools, skillsets, data, etc.) that can be leveraged for follow-on projects. They have already contributed to Taylor's success in obtaining a 3-year, $750k award for LBNL from last year's SunShot soft costs decision science RFP (SEEDS II). There are likely future development opportunities for related research at DOE and other Federal agencies (despite budget uncertainties), at California agencies, and at various foundations/non-profits.

Personnel: Margaret Taylor is supervising the research, with the assistance of Chris Payne. Other project personnel include economics-oriented research assistants and consulting experts in ETA and other areas of LBNL, as well as consulting experts in the outside organizations of Resources for the Future (an environmental economics think tank) and ETH Zurich.

[6] We expect the compilation of comparisons between *ex ante* regulatory projections and *ex post* evaluations in Simpson, R.D., "Do regulators overestimate the costs of regulation?" in *EPA NCEE Working Paper Series*, ENCfE Economics, Editor 2011, EPA National Center for Environmental Economics: Washington, D.C. to be a particularly helpful guide to other references on: regulatory costs; regulatory benefits (including quality); and outcome variables that may be tied to innovation but were omitted from *ex ante* analyses.